MONTANA UNIVERSITY SYSTEM RESEARCH INITIATIVE

Autonomous Aerial Systems for Wildfire Management in Montana

Fourth Quarterly Report – January 23, 2017

Submitted by:

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http://www.umt.edu/aaso/DroneFire/

Executive Summary

This document describes activities, accomplishments, and progress in the *fourth* quarter of DroneFire. Activities are organized by objectives, as reported in the Project OTOs. Accomplishments are mapped to project objectives in this report rather than to milestones within objectives to eliminate redundancies from previous reports. Expenditures and photos are included at the end of the document. Data collection and analysis represent the primary effort in this quarter. The project remains on schedule and within budget.

The most significant progress in the Quarter occurred in two concurrent field campaigns, one in Kalispell, MT and the other in Baxley, GA. In the latter ten-day campaign, three UAS were deployed on 32 fire missions as part of five distinct experiments (described in the report below). In partnership with The Nature Conservancy, drones were integrated into prescribed fire operations to: (1) measure total fire energy using a drone-mounted thermal imager; (2) characterize spatially explicit fire effects by mapping vegetation and fuels pre- and post-fire; (3) create high resolution 3-D fuel beds from high density imagery to correlate with fire behavior measurements; (4) document wave properties and vorticity of flaming front using high speed video to validate theoretical fire behavior models; (5) evaluate utility of drones for conducting fire line inspections.

In the former campaign, fire weather data were collected from drone and balloon radiosondes and ingested into the Weather Research and Forecasting Model (WRF) with the goal of producing fine resolution forecast runs for site specific fire weather applications. Significant accomplishments in this Quarter include refinements of UAS mission protocols for radiosonde measurements, integration of measurements and models, and automation of data ingestion directly from aircraft to WRF.

DroneFire received a new Certificate of Authorization (COA) for our Lubrecht flight facility following extensive negotiations with the FAA. This COA allows drone research to be conducted up to 2000ft AGL and beyond line-of-site of the pilot, provided that a remote observer can simultaneously witness flight operations and communicate with the pilot. This COA's flexibility significantly expands opportunities for drone development and testing, provides new research opportunities to UM and its partners, and will attract additional funding. We continue to work on additional COAs to operate drones at even higher altitudes to benefit ongoing research in fire weather modeling.

Our public-private partnerships remain healthy. We have worked extensively with Skyefish of Missoula on flight training and development of mission planning software for its M4 platform. We are actively engaged with SUATS of Kalispell to acquire radiosonde data and test a variety of sensors, platforms, and a transponder. Our field missions with Commander Navigation of Hamilton were postponed due to winter weather and rescheduled for spring 2017.

Finally, we added one Ph.D. student to the project to assist with efforts to develop capacity and institutional knowledge in UAS research, with two expected outcomes- implementation of fixed-wing pilot training and best practices for UM researchers, and design and construction of a low-cost fixed wing data collection platform.

<u>Objective #1</u>. Develop project management organization and workplan, prepare communications plans encompassing economic impacts, progress, and deliverables; develop strategy for end-of-grant transition to UM AASO

- *Complete*

<u>Objective #2.</u> Establish contracts and coordinate flight operations with Montana's UAS companies and FAA for fly-in/field campaign at Lubrecht Experimental Forest. Overall Purpose: Leverage and grow UM's research enterprise through private sector partnering.

- *Contracts and coordination are largely complete.*
- *One Fly-In (Commander Navigation, Hamilton) was postponed until Spring 2017 due to Winter weather.*
- *We initiated efforts with UM Contracts and Services to lease private aircraft to fly under UM COAs and began collaboration with SUATS to establish procedures to jointly apply for COAs at high altitudes at the SUATS facility in Kalispell.*

<u>Objective #3</u>. Establish field laboratory for UAS research and development, where UAS can be deployed consistently to measure and monitor forest fuels. Overall Purpose: Grow emerging UAS field in MT by providing permanent R&D facility and demonstrating new instruments and technology.

- *Secured new Certificate of Authority from FFA at Lubrecht Experimental Forest. COA allows flight to 2000 ft AGL and beyond visual line of sight for pilot, provided that a remote observer can simultaneously witness flight operations and communicate with the pilot.*
- *Initiated administrative process to extend field laboratory at Sands Unmanned Aircraft Training (SUATS) Facility in Kalispell. Currently SUAT has a 900 ft. X 40 ft. paved runway, pattern dimensions of 2000 ft. X 700 ft., with access to large hanger facility. Use of the facility by UM allows utilization of larger, longer-duration aircraft.*
- *In partnership with SUAT, we are testing a Sagetech UAS Transponder. Sagetech has released proprietary development code to us for testing and integrating the software to the appropriate auto pilot and GPS device for test flights. Obtaining reliable transponder positioning will enable even greater flexibility in flight operations in the future.*
- *Planned and coordinated collaborative meeting at the ALASKA CENTER FOR UNMANNED AIRCRAFT SYSTEMS INTEGRATION (ACUASI) in Fairbanks, AK. (scheduled for April 2017)*
- *Six missions were flown from Droneport in Quarter using rotor-wing platforms; 5 fixed-wing missions flown.*

<u>Objective #4.</u> Develop a science cadre to test applications and conduct research; build infrastructure for data management; produce and test field-usable data products. Overall Purpose: Leverage MUS research enterprise targeted at private sector; build future customer base.

- *Leveraged Funds: National Science Foundation: Biophysics of plant-insect interactions: $887K awarded to Wildlife Biology (Official award pending federal budget passage) - Dronefire has acquired thermal infrared camera to support this effort and is beginning bench calibration of instrument. Field tests for thermal measurements of tree canopies at SUAT facility are scheduled for May 2017.*

- *UAS Fire Weather Project – UAS are being used to acquire measurements of the atmosphere, which are compared with traditional data from radiosondes on balloons. UAS can acquire 6-8 atmospheric soundings per day for the same cost as one sounding using a balloon and the UAS platform is recovered for additional data collection. UAS can also increase the spatial resolution of data and obtain site-specific measurements in the fire environment. DroneFire is developing the technology and methods to transition radiosonde measurements from balloons to drones. This effort involves collecting coincident data by both methods, comparing model outputs at various spatial and temporal resolutions, and consulting with operational NWS forecasters. Project partners are SUATS of Kalispell, NWS, and USFS Missoula Technology and Development Center.*
    - *Refined mission protocols for UAS radiosonde atmospheric measurements to enhance 37m resolution WRF forecast runs. Additional field tests are schedule for late February 2017*
    - *Completing automated process for aircraft and radiosonde data ingestion into WRF model to nudge forecast from field measurements; developed "little-r" conversion algorithm to ingest data into WRF, collaborating with Missoula MTDC to evaluate wx data from manned aircraft and providing sensor operator on flight days.*
    - *Developed data management, archiving, and sharing protocols for weather measurements and WRF outputs.*
    - *Partnered with Missoula National Weather Service Office to refine modeled (WRF) impact of Flathead Lake on temperature and precipitation around the lake. WRF currently indicates lake enhanced precipitation and a warming effect in the winter.*
- *Bench calibrated existing thermal infrared camera at multiple gain settings to produce radiometric temperature data. Continued testing camera performance on field-instrumented burning slash piles at Lubrecht Forest and on prescribed fires in Georgia.*
- *Acquired post-fire stream channel data for stream reach in Lost Horse Creek (Bitterroot Valley) to support NSF-funded Geosciences Proposal.*
- *Acquired drone imagery for remaining Fire-Fire Surrogate Plots at Lubrecht Forest, plus Larson Stem Map reference plots.*
- *Integrated/implemented Real Time Kinematic GPS for precision drone ephemeris.*
- *Completed Georgia Field Campaign (January 4-15, 2017)*
    - *10-day field campaign in SE Georgia. Deployed three UAS on 32 prescribed fire missions as part of five experiments.*
    - *Experiment 1. Purpose: to characterize total fire energy using drone-based thermal imager. Fire Behavior flux packages were installed in field plots to measure total radiant and convective energy. Plots were imaged systematically using drones from multiple altitudes and angles. Eighteen replicates were collected in six prescribed fires.*
    - *Experiment 2. Purpose: to characterize spatially explicit fire effects by mapping vegetation and fuels pre- and post-fire. Data were collected for four prescribed fires in a variety of fuel types, ranging in size from 160 – 375 acres.*
    - *Experiment 3. Purpose: to create high resolution 3-D fuel beds from high density imagery to correlate with fire behavior measurements. Data were collected for two plots by flying a drone 3 meters above the fuel bed and collecting images from many perspectives and altitudes.*

- *Experiment 4. Purpose: to document wave properties and vorticity of flaming front using high speed video to validate theoretical fire behavior models. Flaming fronts were imaged upwind of the flaming front and followed through changing fuels/fire behavior using drones.*
- *Experiment 5. Purpose: evaluate utility of drones for conducting fireline inspections. 2000 meters of fireline was imaged using a thermal radiometer.*

Objective #5. Procure and test two research UAS complementary to private sector systems. Overall

- *Field tested Firefly6 (FF6) vertol UAS on 12 missions, six of them on active fires. Modified FF6 power system for longer duration flight (40-45 minutes of flight and 300 acres on one battery cycle). This is DroneFire's first implementation of a fixed wing platform.*
- *Completed construction of second low-cost vertical-take-off fixed wing aircraft with wide camera bay (Quadranger Vtol (Volantex Ranger EX)). Platform has 60 minute flight time with vertical take-off/ 80 minute flight time with runway take-off fixed wing. Custom-build, open-source control and flight planning software provide useful flexibility for research missions. The benefit of vertol capacity in fire management is take-off and landing without an airstrip combined with the extended flight duration of a fixed-wing.*

Objective #6. UAS UM course development, training and certification. Overall Purpose: Develop more-capable workforce; grow emerging field of UAS applications.

- *Expanding training program to include fixed wing aircraft.*
- *Refining training standards and requirements to meet FAA pilot requirements for faculty, staff, and students to conduct operations under UM COAs.*
- *Funded one additional Ph.D. student for one semester to implement pilot training and best practices for fixed-wing UAS; student is also prototyping a fixed-wing data collection platform.*
- *In Development: Montana Board of Research and Commercialization Technology Grant: Rotary radiosonde UAS: $150K*

Expenditures/Budget Summary to Date

MFRR13					
		Initial Budget	Expense to Date	Encumbrances	Amount remaining
Contracted Services		$ 225,000.00	$ 19,528.80	$ 48,900.00	$ 156,571.20
Supplies		$ 45,000.00	$ 87,441.34		$ (42,441.34)
Communications		$ -	$ 132.36		$ (132.36)
Travel		$ 60,000.00	$ 16,935.27		$ 43,064.73
Salary		$ 334,930.00	$ 185,123.39	$ 77,526.75	$ 72,279.86
Benefits		$ 112,474.00	$ 43,173.94	$ 21,423.76	$ 47,876.30
Tuition		$ 32,596.00	$ 15,204.80	$ 12,000.00	$ 5,391.20
Equipment		$ 80,000.00	$ 42,695.98	$ 7,516.00	$ 29,788.02
Other Services		$ 10,000.00	$ 4,826.46		$ 5,173.54
TOTAL Expenses		$ 900,000.00	$ 415,062.34	$ 167,366.51	$ 317,571.15

DroneFire technician preparing vertol FF6 platform for launch on prescribed fire in Georgia.

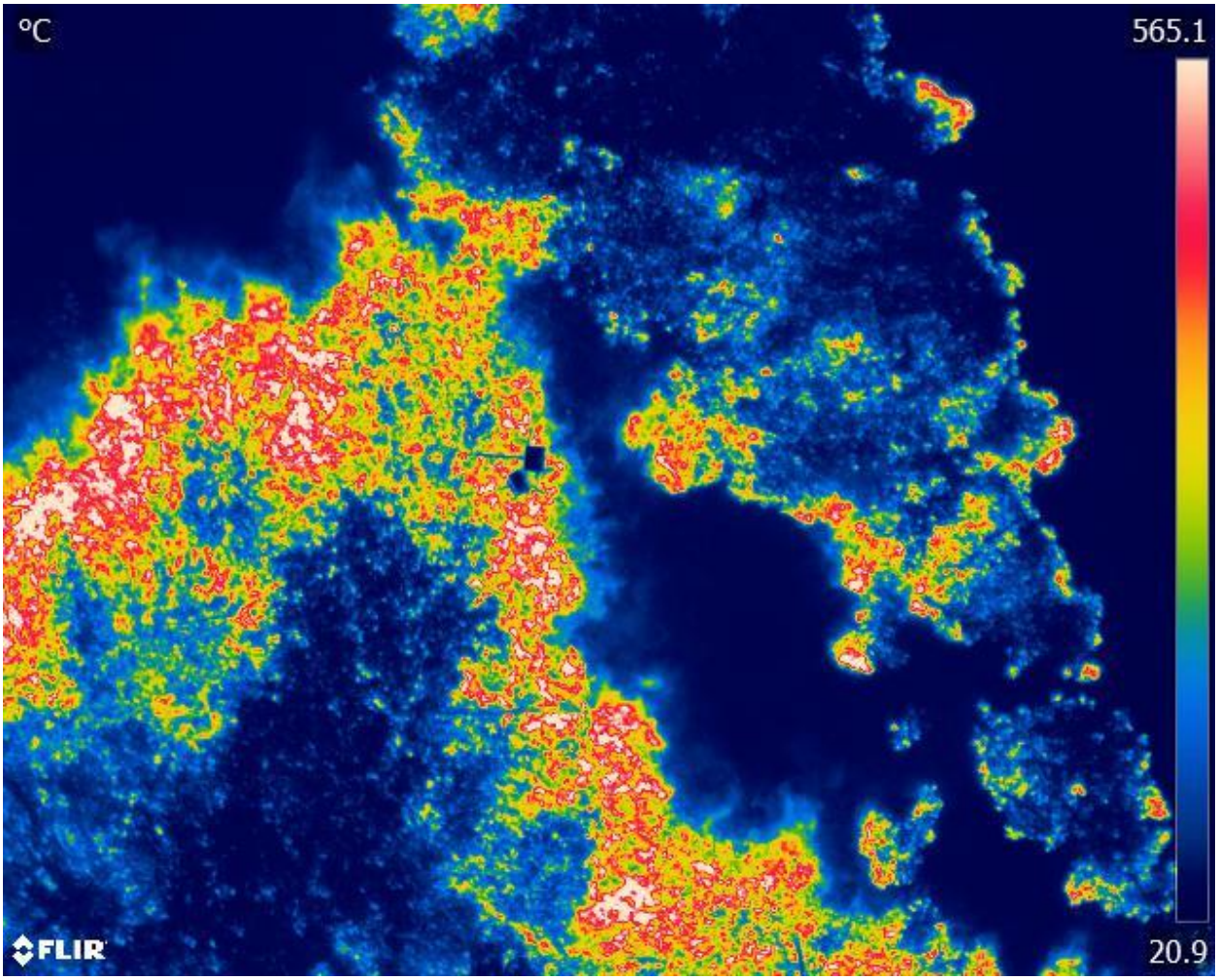
Researchers collecting coincident *in situ* and drone-based thermal data. Sensors in the fire are being used to calibrate thermal imagery from the drones.

Researchers light ignition strip to carry fire into highly instrumented field plots. Drones are being used to characterize thermal energy from multiple look-angles and elevations.

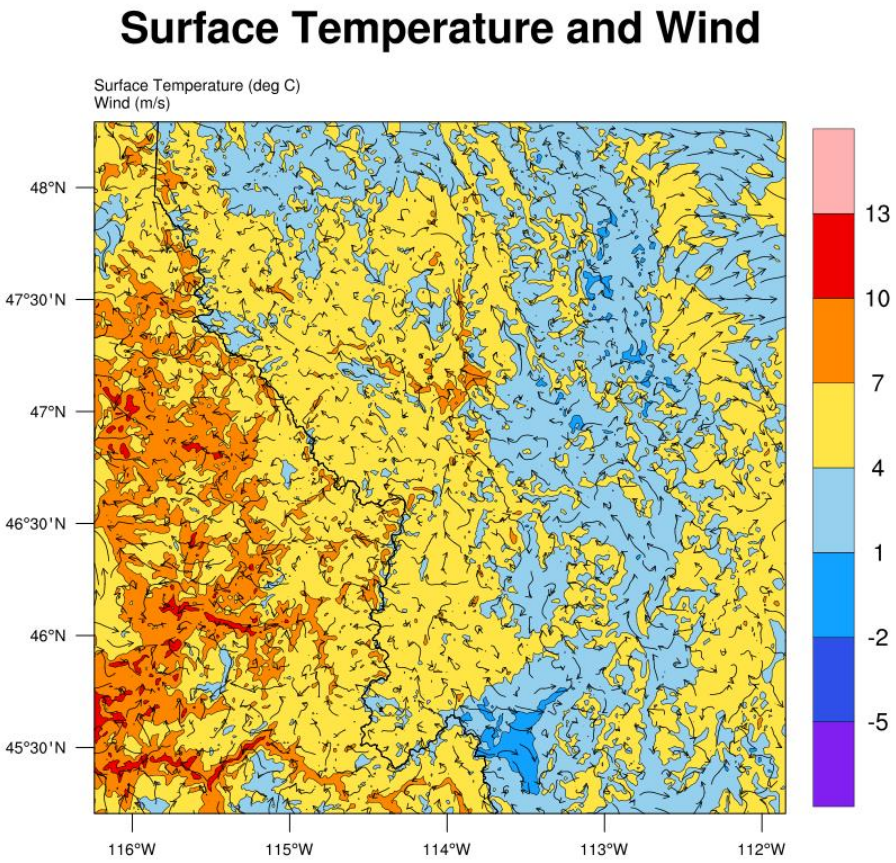
Drone with thermal camera hovering over field plot.

Calibrating thermal camera on burning slash piles at Lubrecht Experimental Forest.

Drone and firefighter.



Calibrated thermal image of fire moving through field plot. Distinct cold rectangles in image center are energy flux sensors installed in the fire itself.



Example 1Km resolution UM WRF model run (11/16/2016). Drone data are being evaluated as a means of refining local fire weather forecasts at fine spatial resolutions.